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To: Coralie Cooper, NESCAUM

From: Dan Meszler, Meszler Engineering Services

Subject: Response to Sierra Massachusetts Pavley Comments

Date: November 22, 2005

Thank you for providing for my review various excerpts[1] from the materials presented by Sierra Research, Inc. during the public comment process for the proposed Massachusetts Pavley regulations. As I understand it, the specific excerpts include all of the material that addressed issues raised by Meszler Engineering Services (MES) in response to comments submitted by Sierra Research during an earlier Pavley public comment period in Vermont.

While I will address each of the Vermont-related comments made by Sierra, I will initially discuss in detail, two issues that underlie the majority of those comments. This will allow me to provide a complete, coherent discussion of these issues as well as allow for subsequent simple reference as appropriate. These two issues are: (1) the proper modeling of any VMT rebound effect related to the adoption of the Pavley program and (2) the proper modeling of any fleet turnover effect related to the adoption of the Pavley program. Both issues are central to the Sierra assertions of Pavley-related increases in criteria pollutant emissions.

Note also that it is my intention to minimize the mathematical elements of all discussion that follows. It is my belief that a detailed mathematical presentation is sufficient to dissuade a substantial fraction of stakeholders from attempting to understand what are essentially straightforward issues, opening the way for scientific intimidation and obfuscation. While limited mathematical concepts are necessary to lay a proper foundation for the issues in question, I will purposefully steer away from detailed statistical discussion and associated coefficients (to the extent practical) in an effort to bring the concepts into clearer focus and allow all stakeholders to weigh with sufficient insight whether any impact related to the specific issues of concern has been properly characterized with respect to Pavley. As always, I would be happy to supplement and increase the precision of these discussions in future followup materials as requested.

[1] The specific excerpts provided were: Sierra Research, Inc., *Evaluation of Massachusetts' Adoption of California's Greenhouse Gas Regulations on Criteria Pollutants and Precursor Emissions*, Report No. SR2005-10-02, October 25, 2005 (report without appendices), plus Appendix F (*Memorandum from NERA to Massachusetts Dept. of Environmental Protection, October 21, 2005, "Response to Comments by Meszler Engineering Services Provided to the State of Vermont as Part of the Proposed Amendments to Control Greenhouse Gas Emissions from Motor Vehicles"*) and Appendix G (*Memorandum from Robert W. Crawford to James M. Lyons, October 24, 2005, "Response to Comments by Meszler Engineering Services in the Vermont Greenhouse Gas Proceeding"*).

In undertaking this effort, I will rely heavily on engineering, rather than statistical, expositions. Statistical analyses can be quite useful in the development of analytical models that allow for the proper evaluation of engineering alternatives, but the utility of such models is determined largely by their ability to accurately recognize and respond to the key physical processes of the underlying engineering phenomena. Statistical models that do so can be quite robust and can lead to important insights that may not be otherwise obvious. Statistical models that are less robust may still be useful, but their utility is constrained (say, for example, to specific physical situations) and such constraints must be recognized to avoid misinterpreting real-world physical responses. As will be shown, the statistical models employed by Sierra to estimate the fleet turnover and VMT rebound effects of Pavley, are constrained in that key physical characteristics related to: (1) vehicle pricing and VMT and (2) vehicle age and VMT, are not accurately represented. As a result, the conclusions of their analysis are unsupportable. While I will primarily demonstrate these weaknesses through engineering analysis, I will, when appropriate, allude to the specific statistical formulations of the Sierra models to assist stakeholders interested in considering the statistical models in detail.

The VMT Rebound Effect. Simply stated, the VMT rebound effect is nothing more than a proper accounting of the cost of driving on driving behavior. If driving becomes less costly, people will be inclined to drive further (since they can go further for a given expenditure). If driving becomes more costly, people will be inclined to reduce driving (since a given expenditure will be reached quicker as driving costs increase). *So the first conclusion that arises from any claim that VMT will increase as a result of Pavley is that the cost of driving must be lower with Pavley than without.* This leads directly to two questions. First, is such a conclusion consistent with the impacts of Pavley? Second, is such a conclusion consistent with other program impact arguments being presented by Pavley opponents[2] (i.e., are the impact arguments of Pavley opponents self-consistent)?

To answer these questions, one must consider the VMT rebound effect and the implications of Pavley with regard to the cost of driving in more detail. Let us first consider the influences which can lead to VMT rebound. Among the influences that can lead to changes in driving behavior for a given set of constant external conditions[3] are changes in disposable income (which results in changes in the proportion of income attributed to the coverage of driving costs), changes in vehicle purchase or maintenance costs (which result in changes in the portion of income attributed to the fixed costs of driving), and changes in the price of fuel or vehicle efficiency (which result in changes in the portion of income attributed to the variable costs of driving).

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[2] Pavley opponents cite the VMT rebound effect as a critical impact of Pavley since any increase in driving (relative to what would have occurred in the absence of Pavley) reduces program benefits and, as highlighted by Sierra, can increase emissions of pollutants not directly affected by Pavley.

[3] By external conditions, I mean non-monetary conditions that are independent of (i.e., not influenced by) a particular monetary influence on VMT demand. Such conditions would include VMT influences such as employment and housing location, recreational activity, driver and vehicle age and condition, etc. These parameters certainly vary from individual to individual, but would be unchanged for any given individual between a "with Pavley" and "without Pavley" (or any other VMT rebound) scenario. Any fleet turnover effects could, obviously, affect vehicle age, but for simplicity in this discussion, I will treat the VMT rebound effect as independent of fleet turnover.

Pavley should not have any significant effect on aggregate disposable income, vehicle maintenance costs, or the price of fuel. While there could be minor changes in income (either positive or negative) in areas with significant vehicle manufacturing infrastructure or minor changes in maintenance costs (either positive or negative) due to vehicle redesign issues, these will be secondary effects with limited impact not significantly different than any other influence affecting the motor vehicle industry. It can, however, be argued that Pavley will result in changes in fuel price due to reductions in fuel demand (as a result of improved vehicle efficiency).[4] However, I will assume that such price changes are insignificant for two reasons. First, the assertions of Sierra do not consider fuel price changes.[5] Second, petroleum production is artificially constrained (even without Pavley) to control costs and there is no reason to believe that such control would not be adjusted (if necessary) to maintain desired pricing pressure with Pavley. As a finite resource, the overall value of petroleum in a controlled production and distribution market is unaffected by the time required to consume that resource (Pavley would extend the life of the resource, not alter its value). Whether this assumption proves true or not has no affect on the remainder of the VMT rebound discussion, but any actual changes in overall fuel price would serve as an *additional* VMT influence that would have to be considered alongside those identified in the remainder of the discussion. Perhaps most importantly, whether fuel pricing is maintained or not is an issue associated with *any* fuel conservation program. In affect, a fuel price rebound argument could be used as a perverse rationale for not considering any fuel conservation program.

The most important monetary impacts of Pavley are changes in vehicle price and changes in vehicle efficiency, *both* of which must be accounted for in assessing any associated VMT rebound. My major criticism of the Sierra work is that they consider only the impacts of the latter. It is perhaps worth clarifying that it is my opinion that the effects of both influences *could* be derived from the statistical analysis approach employed by Sierra to estimate the rebound effect, it is simply that they have chosen to isolate the impacts of only one effect in both their discussion and treatment of VMT rebound.[6] Because of this, the effect is overstated by a considerable margin in their analysis.

I will attempt to explain my continuing disagreement with Sierra's approach through engineering example rather than a detailed statistical discussion, but those interested in further examination of the specific statistical weaknesses of the Sierra approach should review the later comments related to Appendix G of the Sierra Massachusetts report. It is critical to initiate the discussion by stating flatly that the fundamental issue of concern is that Sierra's VMT rebound estimate is based on an estimated statistical response to changes *only* in the variable cost of driving (i.e., only changes in vehicle efficiency are considered). Thus, their derived elasticity estimate does

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[4] If overall fuel demand declines, the relative supply of fuel will be greater "with" than "without" Pavley resulting in a downward pricing pressure.

[5] In other words, a constant fuel price assumption is consistent with that employed by Sierra in their analysis of the VMT rebound effect, so that it does not contribute to our differing opinions.

[6] To be fair, it should be recognized that Sierra does not intentionally ignore either effect. Instead, the statistical model they use was unable to isolate the impact of vehicle pricing on VMT so that their use of that model inherently assumes that VMT is independent of (i.e., is not affected by) changes in vehicle price. The specifics of this will be discussed in more detail below in the specific comments related to Appendix G of Sierra's Massachusetts report.

not consider the increased fixed (i.e., purchase) costs associated with the purchase of a Pavley vehicle.[7] This explains, for example, why their derived elasticity estimate agrees with corresponding elasticity estimates developed by other researchers on the relationship between the variable costs of driving and VMT but, at the same time, overestimates the Pavley rebound effect.[8]

My hope is that a few examples will illustrate the deficiency quite plainly. Let's start with the simplest example, a change in fuel price. This is an ideal case as vehicle purchase price is unchanged and all drivers are affected immediately and equivalently by the fuel price change. In effect, their cost of driving changes directly with fuel price. If fuel price rises, VMT will decline in accordance with the cost-per-mile elasticity.[9] If fuel price declines, VMT will increase in accordance with the cost-per-mile elasticity. When VMT rebound elasticities are calculated and discussed, it is this cost-per-mile elasticity that is referenced and Sierra's work is no different. This is a valid and informative approach, *but its application is limited in instances where other factors related to the cost of driving are also affected, as is the case with Pavley*.

With Pavley, the cost of driving is influenced not by fuel price changes, but by changes in vehicle purchase price and efficiency. This has two implications that should be recognized in considering Pavley impacts. First, Pavley has no immediate impacts on existing vehicle owners, whose cost of driving is unaffected until such time as they elect to purchase a new vehicle. Second, when affected, drivers are subject to opposing influences -- an increase in their vehicle purchase price (relative to a non-Pavley vehicle) and a decrease in their fuel-related operating costs (relative to a non-Pavley vehicle). The combined effect of *both* of these influences determines the Pavley impact on VMT.

From Sierra's spreadsheets submitted with their comments to Vermont, they assume an approximate 15-30 percent decrease in fuel-related operating costs per mile and an increased vehicle purchase price of $1,000-$7,000. For simplicity, let's look at a case of a 23 percent decrease in fuel-related operating costs with an associated vehicle price increase of $4,000 as representative of their average assumptions. Changes in *variable* operating costs are directly equivalent to changes in fuel prices for those drivers that purchase a Pavley vehicle. So the Sierra elasticity can reasonably be taken as representative[10] of the impact of the *variable* portion of the operating cost influence. However, unlike a fuel price change, the decrease in variable costs does not come for free -- drivers must pay the incremental price of the Pavley vehicle to

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[7] Sierra would (and does) disagree with this assertion, by insisting that their statistical model does include a proper consideration of vehicle pricing effects. However, as will be documented in the specific comments related to Appendix G of Sierra's Massachusetts report, their model includes only a statistically insignificant coefficient for vehicle price, so that price impacts are effectively assumed to have no impact on vehicle fleet size (and thus VMT).

[8] Recognize, however, that this is not intended to endorse any elasticity estimate, but rather provide an indication as to why even apparently consistent estimates can lead to incorrect conclusions.

[9] Elasticity is simply an economic term indicating the change in one parameter relative to the change in another. In the case of this discussion, it would indicate the change in VMT per unit change in the cost of driving.

[10] Ideally, I would perform a detailed statistical analysis to quantify this parameter independently, but such an exercise is not necessary to illustrate the critical points of the discussion. Thus, while I am not endorsing the Sierra elasticity estimate, it is adequate for illustrative purposes.

achieve the variable cost decrease. This price increase *directly and unequivocally* affects the incentive to increase (or decrease) driving in response to Pavley.

To illustrate this, consider a typical useful vehicle life of 150,000 miles. At a $4,000 price premium, Pavley vehicle owners will pay the equivalent of an *incremental* 3.0 cents per mile to purchase their vehicle.[11] Although variable operating cost savings are sensitive to both fuel price and the assumed efficiency of the non-Pavley baseline vehicle, savings over 150,000 miles for an average fleet vehicle[12] will range as follows:

Fuel Price (dollars per gallon)	$1.50	$2.00	$2.50	$3.00	$18.00
Efficiency Savings (cents per mile)	1.6	2.2	2.7	3.3	19.7

This means that the *net* operating cost savings (incremental vehicle purchase price minus efficiency savings) will range as follows:

Fuel Price (dollars per gallon)	$1.50	$2.00	$2.50	$3.00	$18.00
Net Savings (cents per mile)	-1.3	-0.8	-0.2	0.3	16.8

Negative savings indicate operating cost increases.

Clearly, for Sierra's price and efficiency impact assumptions, Pavley vehicle purchasers will not observe a net operating cost decrease though 150,000 miles unless fuel prices remain above $2.70 per gallon. In effect, a $2.70 fuel price generates no net change in Pavley vehicle operating costs over 150,000 miles based on Sierra's purchase price and efficiency impact estimates. Therefore, given their assumptions, vehicle purchasers have no economic pressure to increase VMT unless fuel prices exceed $2.70 per gallon throughout the 150,000 mile vehicle life and, even in such circumstances, every additional mile driven under Pavley *reduces* net savings.

Another way of looking at these same data is to calculate the break-even point (the point where efficiency savings just offset increased vehicle purchase price) for the various fuel prices. These points, expressed in terms of both years and miles, are as follows:[13]

Fuel Price (dollars per gallon)	$1.50	$2.00	$2.50	$3.00	$18.00
Break-Even Point (years)	>25	18.7	12.8	9.8	1.3
Break-Even Point (miles)	>229,999	203,017	162,413	135,344	22,557

[11] For the examples in this discussion, I assume a five year vehicle purchase loan at 5 percent per year, an 8 percent sales tax on the incremental vehicle purchase price, and an economic discount rate of 5 percent. However, the similarity of the assumed loan interest rate and the economic discount rate render the calculations substantially equivalent to those for a zero percent interest, zero discount analog. The only effective difference results from the monthly compounding of the purchase loan, which is minor.

[12] 420 grams CO_2 per mile, based on an assumed 50/50 sales split between passenger cars and light trucks.

[13] Based on MOBILE6.2 average annual mileage accumulation rates for light duty vehicles. The MOBILE6.2 mileage accumulation function ends at 25 years and 230,000 miles and I did not attempt to extrapolate beyond this point.

In practice, these break-even points can be viewed as the *earliest* point at which operating cost savings would begin to "pressure" vehicle owners into increasing VMT. Prior to these points, there is actually an economic incentive to *decrease* VMT to minimize operating cost increases. Please recognize that I am not suggesting that such decreases will occur as I have fundamental disagreements with Sierra's price and efficiency impact assumptions, *but that is the direct and consistent VMT implication if one accepts their impact assumptions*.

To further illustrate this, let's look at these same data via one additional perspective. If we assume the same cost-per-mile VMT elasticity as Sierra (i.e., -0.157) and look at above tabulated operating cost (i.e., cent per mile) impacts in terms of equivalent dollars per gallon,[14] then the following fuel price equivalent impacts are observed:

Fuel Price (dollars per gallon)	$1.50	$2.00	$2.50	$3.00	$18.00
Considering Only Efficiency Improvements (the Sierra Approach)					
Fuel Price Equivalent Impact (dollars per gallon)	-$0.45	-$0.60	-$0.75	-$0.90	-$5.38
Equivalent Change in Fuel Price	-29.9%	-29.9%	-29.9%	-29.9%	-29.9%
Economic VMT Pressure	**+4.7%**	**+4.7%**	**+4.7%**	**+4.7%**	**+4.7%**
Considering Net (i.e., Purchase and Efficiency)150,000 Mile Operating Cost Impacts					
Fuel Price Equivalent Impact (dollars per gallon)	+$0.36	+$0.21	+$0.06	-$0.09	-$4.57
Equivalent Change in Fuel Price	+24.0%	+10.6%	+2.5%	-2.9%	-25.4%
Economic VMT Pressure	**-3.8%**	**-1.7%**	**-0.4%**	**+0.5%**	**+4.0%**

The values in red font are indicative of the VMT impact assumptions employed by Sierra[15] and reflect the economic pressure on VMT if one ignores the purchase price impacts of Pavley. The values in green font are indicative of the corresponding economic pressure on VMT if one considers all of the economic impacts of Pavley, as defined by Sierra. As observed, the net pressure on VMT is downward for fuel prices under about $2.70 per gallon (as vehicle purchase price impacts outweigh efficiency benefits). Additionally, even at higher fuel prices, the economic pressure to increase VMT is significantly smaller than that associated with the Sierra approach (since that pressure only accrues after purchase price impacts are recouped). As indicated, the economic pressure does not even approach that assumed by Sierra until fuel prices approach $20 per gallon.[16]

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[14] Cents per mile is directly convertible to dollars per gallon by multiplying the cent per mile impact by the associated Pavley vehicle efficiency.

[15] The tabulated values do not exactly match those used by Sierra since my illustrative exercise is based only on assumed average price and efficiency impacts, while their values will vary by vehicle type and year. Nevertheless, the tabulated data are representative of their approach and its magnitude.

[16] To be fair, it should be recognized that the Sierra elasticity estimate used for this comparison is based on changes in variable operating costs only and that the net change in total operating costs for these same data would be smaller. For a constant VMT response, this would imply a larger elasticity estimate but it is not possible to accurately quantify the effect without performing a complete statistical analysis using total operating cost data in lieu of variable operating cost data. While this could indicate that the economic pressure to alter VMT might be larger than shown in the example, it will not affect the crossover point at with the economic pressure changes from negative to positive.

As indicated in the introductory remarks, this entire discussion can be reframed into a statistical discussion. However, I do not think that such reframing is required for the inconsistencies of the Sierra VMT argument to be evident. Sierra claims that the incremental price of Pavley vehicles will be at least three times larger than the operating cost benefits to consumers. If this is the case, why would vehicle purchasers exacerbate their financial losses by actually increasing their demand for travel? In short, Sierra's economic analysis is not consistent with their VMT rebound analysis and one or both must be incorrect.[17]

Finally, it is important to note that this discussion is not intended to dismiss the VMT rebound effect. I am simply pointing out that that effect as estimated by Sierra is not consistent with their price and efficiency impact assumptions and therefore their analysis cannot be taken as coherent. However, if more appropriate vehicle price and efficiency impacts are assumed (such as those assumed by the California Air Resources Board), then upward economic pressure will be exerted on VMT (as efficiency benefits outweigh vehicle costs). In such a case, the upward pressure on VMT could approach 3-4 percent for fuel costs in the $2.50-$3.00 per gallon range *if one assumes the Sierra VMT elasticity coefficient cited above is accurate*. Of course, I would prefer to conduct my own statistical analysis to quantify the elasticity value before accepting that proffered by Sierra.

The Fleet Turnover Effect. Essentially, the fleet turnover effect can be viewed as the change in vehicle sales that results from a change in vehicle cost. If vehicle cost increases, sales decline, and the fleet takes longer to turnover. If vehicle cost decreases, sales increase, and the fleet turns over more quickly. Notice that I use the term "cost" rather than price in this context for explicit reasons. Cost need not change in accordance with price. For example, if a vehicle owner obtains a net operating benefit of $50 from a technology that has been added to a vehicle for a price increase of $40, the cost to the consumer has declined by $10 while the vehicle price increased by $40. Accordingly, the fleet turnover effect is a function of price plus other attributes that together define the net cost to the consumer.

For example, as cited above, Sierra estimates an average new vehicle price increase of about $4,000 due to Pavley. From the VMT rebound discussion and their own explicit statements, it is clear that Sierra assumes that the associated efficiency impacts will not be sufficient to offset the increased vehicle price and there will, therefore, be a net cost to the consumer.[18] Additionally, it is widely claimed that consumers do not value efficiency increases over the full useful life of a vehicle, but rather perceive a discounted value that is subject to considerable uncertainty. Attempts to quantify the specific discount assumed by consumers have been performed, but the variability of results is significant. While I cannot state with confidence what specific efficiency value function is assumed in Sierra's work (since it is not explicitly described in their report), it is almost certain that they have assumed a "pessimistic" consumer efficiency valuation. Thus, before even considering the dynamics of the Sierra analysis, one must view their fleet turnover impacts as representative of a high cost, low efficiency, low efficiency value analysis. In effect,

[17] Interested readers are further referred to the detailed responses to assertions made in Appendix G of Sierra's Massachusetts report for a discussion of the specific statistical weakness that renders the statistical analysis used by Sierra to estimate VMT rebound as deficient in regard to its ability to properly consider Pavley impacts.

[18] Once again, I am only clarifying the Sierra assumptions here so that we can view the consistency of their arguments. I am in no way stating my agreement with those assumptions.

they have performed a worst case Pavley fleet turnover scenario (they, of course, would disagree with this assessment). At a minimum, the sensitivity of their results to a more "optimistic" efficiency valuation function should be presented.[19]

Regardless of the sensitivity of the Sierra fleet turnover estimates, the application of those estimates to the determination of criteria pollutant impacts is fatally flawed despite protestations to the contrary. The flaw stems directly from the failure of Sierra's analysis to account for the VMT effects of *their own* forecasted changes in fleet size. In effect, they assume that demand for VMT will be unchanged[20] despite estimates of a significantly reduced fleet size.

Sierra takes great care to demonstrate their estimated reductions in new vehicle sales and the associated impacts on fleet turnover rates. Of course, these impacts depend directly on Sierra's new vehicle price, efficiency, and efficiency valuation assumptions. However, nowhere do they mention that the overall size of the fleet is also forecasted to change directly with new vehicle purchases. In effect, drivers are holding on to older vehicles longer, but they are *not* replacing scrapped vehicles on a one-to-one basis -- the overall size of the fleet is shrinking. This presumably is the result of an economic decision by consumers to reduce vehicle ownership rates in the face of the assumed new vehicle price increases. Such responses would be economically consistent with a perception of diminished utility cost-effectiveness (i.e., a perception that price increases outpace utility increases), but the effects of such responses must be considered on related consumer behavior (specifically demand for travel). Sierra does not take these related effects into consideration.

Understand that it is not my speculation that overall fleet size should be declining given Sierra's cost and efficiency impact assumptions. All of the data presented in this discussion are taken directly from Sierra's own spreadsheets for their Vermont Pavley analysis. For example, Figure 1 graphically shows *their* forecasted light duty vehicle fleet sizes in Vermont with and without Pavley. As shown, new vehicle sales are estimated to decline by about 10,500 vehicles per year by 2030 (an approximate 26 percent decline), while the total fleet size is reduced by nearly 91,000 vehicles. Thus, nearly nine years of sales are not simply displaced by the retention of older vehicles, but by a decision not to purchase a replacement vehicle. Because of this, the average age of the fleet only increases by about 1.5 years despite the dramatic forecasted reduction in sales.

At the same time that Sierra estimates these dramatic changes in the Pavley vehicle fleet, they estimate *no* changes in the fleet VMT (exclusive of the rebound effect that is treated separately). Consumers are expected to drive exactly the same number of miles despite the fact that the size of the fleet has declined by 15 percent. Even ignoring the obvious relationship between supply (available vehicles) and demand (VMT), one need look no further than Sierra's own statistical analysis conducted in support of their VMT rebound impacts to view the significance of vehicle stock (i.e., fleet size) on VMT demand. From that analysis, it is clear that the relationship between vehicle stock and VMT is direct and highly significant. VMT should increase or

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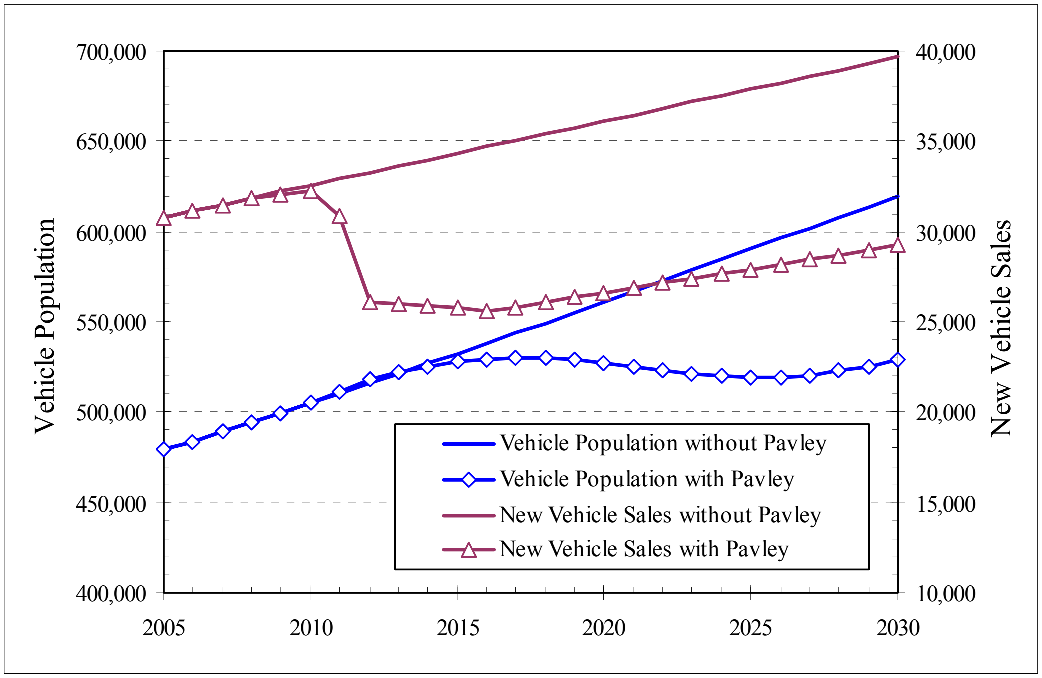
19 Some indication of this sensitivity is observable in the detailed responses to comments presented in Appendix F of the Sierra Massachusetts report, where the fleet turnover impacts of three varying vehicle price and efficiency scenarios are compared.

20 Exclusive of efficiency-driven rebound effects which are treated separately as previously described.

Figure 1. Sierra's Estimated Fleet Size Impacts (Vermont)



decrease with fleet size. In effect, Sierra's fleet turnover VMT assumption is not consistent with their own statistical analysis showing that VMT is quite significant to fleet size.[21]

Although Sierra's analysis is clearly deficient, suppose (only for the sake of argument) that we ignore the relationship between fleet size and VMT and assume that Sierra's assumption of no change in VMT is correct. In such a case, fleet vehicles must be driven more with Pavley than without. On a fleet average basis, vehicles have to be driven about 17 percent further with Pavley to offset an approximate 15 percent decline in fleet size. This means that vehicles with Pavley will be subject to quicker (on a time basis) deterioration and more rapid increases in maintenance costs than the same vehicles without Pavley, implying that scrappage rates with Pavley will be a function of *both* perceived new vehicle utility cost-effectiveness and accelerated vehicle depreciation (due to greater usage demands). Sierra considers only the former.

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[21] Sierra confuses this relationship often in their comments when they claim that VMT is not sensitive to changes in fleet size. What their statistical models for the VMT rebound effect show is that VMT *is* sensitive to fleet size, but that fleet size is not sensitive to vehicle price. As a result, they deduce that Pavley will not affect fleet size (in the rebound model) and thus not affect VMT (exclusive of the rebound effect). However, their fleet turnover model directly contradicts the rebound model by showing that fleet size is dependent on vehicle price and thus, the constant VMT argument falls flat. In effect, the two models produce contradictory predictions of fleet size.

It is also important to note that accomplishing the same level of travel with a smaller fleet implies increased operational efficiency. This means that there are fewer unused vehicles with evaporative emissions and decreased soak times between trips. While I have not attempted to quantify the effect of this increased efficiency, it can only result in a decrease in criteria pollutant emissions relative to any analysis that does not consider the increased operational efficiency implicit in a reduced size, constant VMT fleet.

Thus, Sierra's fleet turnover analysis is deficient regardless of whether one agrees with their assumption of no VMT change for a smaller fleet. If one believes that VMT demand is a function of fleet size, then the Sierra analysis is clearly deficient since no such relationship was considered. If one ignores this relationship, then the Sierra analysis is deficient for not considering the effects of increased operational demand on vehicle scrappage rates and increased operational efficiency. One or the other must be considered to derive an internally consistent impact estimate.

Additional Responses to Sierra's Assertions in their Massachusetts Pavley Report:

1. Sierra asserts that I failed to properly credit a rebuttal to Hwang's[22] historic review of compliance cost estimates relative to actual compliance costs (see page 38 of the main body of their Massachusetts report). Although I am not signifying any agreement with the cited rebuttal, the comment is valid. It was (and is) not my intention to initiate another round of technology cost arguments, as such costs have been the focus of detailed and continuing analysis by both CARB and industry (through Sierra). I would simply advise stakeholders that significant disagreement exists with regard to both Pavley and historic compliance cost estimates and that those interested in developing an informed opinion as to the most likely compliance costs should review the existing materials that have been generated by both regulatory supporters and industry. While I disagree with Sierra's cost estimates, that disagreement does *not* affect my principal technical objections to Sierra's Pavley criteria pollutant impact analysis.

2. Sierra asserts that the credit trading allowances available under Pavley offer no practical relief to the industry, as the credit system cannot be reliably implemented within the constraints of the industry design and manufacturing process (see page 38 of the main body of their Massachusetts report). While I disagree with the premise and believe that trading agreements can be established within the framework of the automotive market, my (and Sierra's) belief is absolutely irrelevant to the actual compliance costs of the program. From a practical standpoint, all that matters is the actual compliance costs of individual manufacturers as each will still be able to earn and use credits across their own product lines. Manufacturers that elect to abandon one segment of the vehicle market to focus efforts on another where their cost of compliance is more cost competitive with that of their competitors escape nothing by doing so since their competitors will still be able to generate lower cost credits in the non-competitive segments and transfer those credits to minimize their own compliance costs in the various market segments in which the "fleeing" manufacturer chooses to compete (thus simply transferring the very cost disadvantages the "fleeing" manufacturer is trying to escape). In short, if there is a compliance disadvantage, it is not ameliorated in any way by dropping out of a market segment and allowing competitors to

[22] "*Comments on the NAS Study on State Practices in Setting Mobile Source Emission Standards*," Roland J. Hwang, Natural Resources Defense Council, January 19, 2005.

generate emission reduction credits that can then be used to reduce their compliance costs in a competitive market segment.

Inter-manufacturer trading is the only viable way to eliminate compliance cost differentials (if they do exist) and it is simply short-sighted to think that manufacturers cannot negotiate (up front) a credit generation contract that stipulates specific monetary "penalties" should the generating manufacturer default on the agreement.[23] Both NMOG and ZEV credits have been generated and exchanged. While the scope of those credit programs may not approach that of a Pavley trading program, that is only because manufacturers have been able to comply with the NMOG and ZEV requirements without undue hardship. If such turns out to be the case for Pavley, I would also not expect to see significant trading -- but the allowance does exist precisely to alleviate the very market situations that Sierra is touting as a rationale to abandon specific market segments. Sierra is correct in stating that I have not performed a detailed economic analysis of Pavley, however a detailed analysis is not required to understand that allowing a competitor to gain a monopoly in one market segment is not going to assist the "fleeing" manufacturer in transferring the lost market share to another. It would be more economical to enter into a credit agreement. Yes, such an agreement would undoubtedly require a premium payment relative to the cost of credit generation, but such a premium would be substantially reduced from the cost of "independent" compliance in a higher cost market segment.

3. Sierra asserts that my comment that they do not properly account for the operating cost gains associated with Pavley vehicles is unfounded (see page 39 of the main body of their Massachusetts report). Their assertion is premised on information presented in Appendix F of their Massachusetts report, so I will defer my response until the material from that appendix is discussed in detail below.

4. Sierra asserts that my comment of the improper treatment of older vehicle VMT is unfounded (see page 39 of the main body of their Massachusetts report). They refer again to information presented in Appendix F, so I will again defer comment until the detailed discussion of that appendix below.

5. Sierra dismisses as unfounded my comments that a Pavley compliance strategy based on advanced hybrid vehicles may have associated criteria pollutant and compliance cost benefits (see page 40 of the main body of their Massachusetts report). While I do not desire to belabor these points as I believe it detracts from the major issues of concern with the Sierra analysis (fleet turnover and VMT rebound), it is my continuing belief that a hybrid-based ZEV compliance strategy will have significant overlap with a hybrid-based Pavley compliance strategy, as proposed by Sierra. Any manufacturer that expects to rely on a full or partial hybrid compliance strategy for both ZEV and Pavley requirements will claim "redundant" expenses if they try to allocate the full cost of hybrid design and production to both programs. This does not mean that Pavley expenditures will be zero, simply that Pavley costs are the net difference between total hybrid expenses and those expected to be incurred under ZEV program requirements alone.

[23] Of course, I state this without advantage of legal counsel. While I do not believe that there are legal impediments to such agreements, it is possible that I am incorrect.

With regard to criteria emissions impacts, if hybrids do indeed have lower criteria pollutant emissions, the ability of the industry to "balance" those lower emissions by selling "greater numbers of vehicles in higher emitting categories" (as asserted by Sierra) will be significantly limited by two requirements. First, the Pavley standards must be met and Sierra's analysis implies that such standards will demand a predominately hybrid fleet. Second, LEV-II requirements prohibit the sale of models with higher emissions than those sold federally under the Tier 2 program. Therefore, Tier 2 certifications act as a second "cap" on the ability of the industry to sell higher emitting vehicles in LEV-II states. Nevertheless, as I stated in my initial comments to Vermont, there is no regulatory requirement that would directly require hybrids to have lower criteria pollutant emissions. Therefore, in the interest of focusing on those effects central to Sierra's analysis (fleet turnover and VMT rebound), I will not pursue either of these arguments further, but recommend that stakeholders consider both issues carefully.

6. Sierra asserts that the empirical data showing that vehicle sales in Vermont outpaced national vehicle sales following Vermont's adoption of the LEV-II program is irrelevant (see page 41 of the main body of their Massachusetts report). While I included this data for illustrative purposes, it is not central to the arguments that Sierra's fleet turnover and VMT rebound impacts are overstated. Additionally, their assertions reference information presented in Appendix F, so I will defer any significant comment until the discussion of that appendix.

However, I will comment briefly on specific assertions made by Sierra with regard to these data that do not appear elsewhere in their report. First, I do not believe that LEV-II compliance costs are in the range of $1,000-$7,000 as asserted by Sierra. That cost range was extracted from the previously referenced Hwang presentation, which, as I have previously stated, should be viewed in the context of any rebuttal information provided by Sierra or others. I have not had an opportunity to review such rebuttal information, so I will defer any additional value judgment. The key point here is not the absolute level of price increase, but the fact that vehicle prices did rise with no offsetting increase in utility relative to vehicles sold federally. Therefore, one would expect to see a sales depression. It is not the size of the depression that is important, merely its presence. As Sierra states, the mere fact that a depression is not observed does not "disprove the predicted effects of NERA's Fleet Turnover Model," but the effects predicted by that model would be bolstered considerably if the expected depression was present. Weighing theory against reality is always difficult due to any number of simultaneously occurring influences (and one would always like to have as much data and as "orthogonal" a set of comparative options as possible), but at some point the theoretical effect either becomes evident or it's validity must be questioned. Perhaps that point is not yet reached with the restricted LEV-II data presented, but it certainly does nothing to support the accuracy of their fleet turnover model. It is not the basic economic effect that is questioned, merely its size and impact.

7. Sierra asserts that my comment that they have ignored important fiscal influences in the development of their VMT rebound estimate is without foundation (see page 42 of the main body of their Massachusetts report). Their assertions primarily reference information presented in Appendices F and G of their report, so I will defer any significant comment until the discussion of those appendices. However, they also state that my "concern is without merit because the impact of increased new vehicle prices, which MES suggests is important, is in fact trivial." While I suspect that Sierra intends to limit the "triviality" of the new vehicle price increases to the rebound effect only, stakeholders should wonder how the new vehicle price increase can be "trivial" from a VMT perspective while being so significant as to reduce new car

sales by about 25 percent and total fleet size by about 15 percent from a fleet turnover perspective. Trivial here, non-trivial there. Apparently, those consumers who do opt to purchase new vehicles do so with the intention of maximizing their economic pain by failing to utilize their operating cost savings to offset the "trivial" new vehicle price increase. It is also interesting to note that despite numerous claims that analysis done in California is irrelevant to the northeast and cannot be relied upon for any purpose, that Sierra actually offers an affirmative defense for their rebound analysis by claiming that "the methodology used in our analysis is essentially the same methodology used by CARB in its evaluation of the rebound effect." While this surely does not detract from the Sierra analysis, neither does it imply that application of their analysis findings is correct (as will be demonstrated below).

8. Sierra asserts that the empirical data I used to support my contention that the VMT rebound effect was overstated is irrelevant (see page 42 of the main body of their Massachusetts report). Here again, their assertions primarily reference information presented in Appendices F and G of their report, so I will defer any significant comment until the discussion of those appendices below. However, they also characterize the traffic count data I used as "questionable," so I would like to briefly respond here to that assertion. I took great care to select that set of traffic count data that was complete for the entire period analyzed. Counters with partial data were not included, so that every counter offers a complete snapshot of data over a six year period. I also made every attempt to factor out seasonal effects by selecting a single investigation month during each year (June). I do assume that Vermont has selected appropriate monitoring locations to characterize traffic in the state, but have no reason to suspect that such is not the case. Regardless, the traffic count data depicts consistent VMT trends over the six year period for those locations included in the database. The data are not manipulated in any way and reflect a reasonable attempt to translate theory into reality given available time and financial resources.

9. Sierra asserts that any decrease in criteria pollutant emissions associated with recent gasoline price increases are irrelevant in that Pavley will lead to higher emissions than would otherwise be the case in a non-Pavley scenario (see page 43of the main body of their Massachusetts report). This is true to the extent that one accepts the fleet turnover and VMT rebound impacts offered by Sierra. I, of course, do not believe that their vehicle price and VMT impacts are self-consistent, as argued in the introductory sections above and the discussions of Appendices F and G below. My sole point in offering this consideration is that *absolute* criteria pollutant emissions could still be below those forecasted in the non-Pavley baseline inventory developed by regulators if the VMT rebound effect is as large as Sierra believes that it is, since VMT will have declined significantly due to recent gasoline price increases relative to the VMT levels assumed by regulatory planners. Nevertheless, Sierra is correct that a non-Pavley scenario would have lower emissions than a Pavley scenario (assuming, of course, that one accepts their rebound analysis).

Further Responses to Assertions in Appendix F:

10. On page 2, Sierra[24] asserts that my comments for Vermont were "often unclear and poorly documented (e.g., its purported "corrections" are not explained or documented)." At the same time, my qualification of having claimed "time constraints" as a rationale for including less

[24] In this context and throughout this memorandum, I use Sierra as a general indicator of Sierra and their subcontractors, National Economic Research Associates, Inc. for Appendix F and RWCrawford Energy Systems for Appendix G.

detailed analysis is offered by Sierra in several cases as an implication that the associated work was either shoddy or unfounded. Although not important from a technical standpoint, I take exception with these assertions. It should be recognized that my comments to Vermont were not intended to represent a detailed technical report, but rather were prepared in a very short timeframe for consideration by Vermont regulators based on my quick reading and abbreviated consideration of Sierra's comments to that state. As requested by Vermont regulators, the entire review was conducted in less than one week -- including time required to catalog, read, and consider Sierra's written and supporting analysis materials. To the extent that my comments reflect this "rush" I offer my apologies to Vermont regulators, but I will do not believe that substance of those comments is either unclear or their associated utility compromised. As always, I would be happy to conduct a more detailed analysis with an associated technical report upon request. Regardless, none of this affects my continuing concerns with the Sierra work -- *that are entirely consistent with those initially prepared for Vermont* -- as documented in this memorandum.

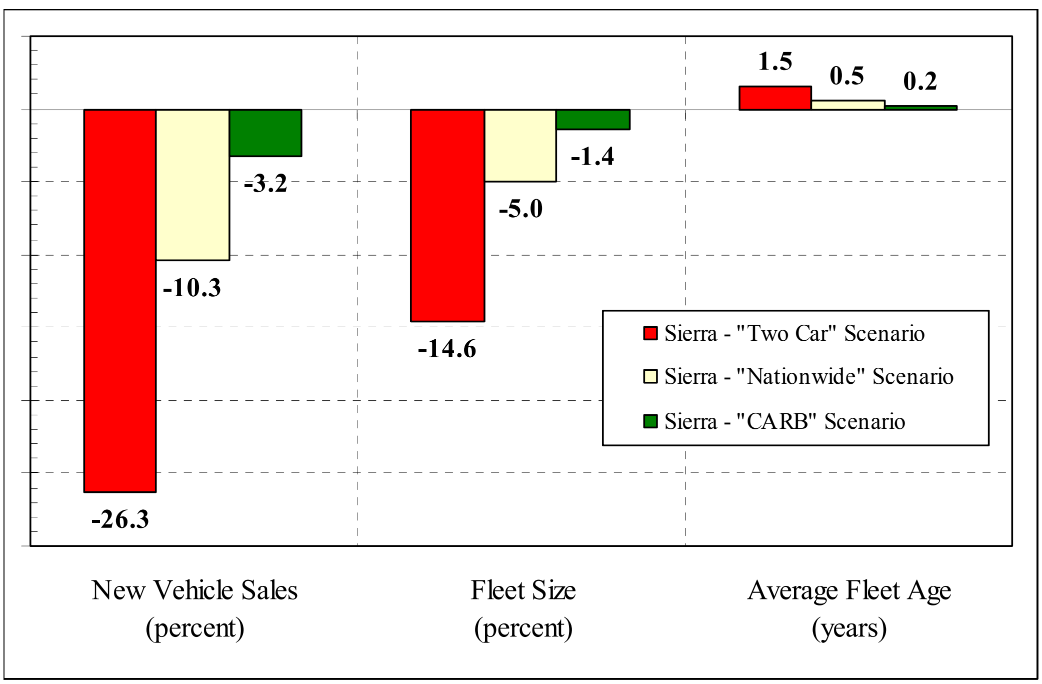
11. On page 3, Sierra asserts that "the Fleet Turnover Model explicitly and properly accounts for consumers' gains from reductions in vehicle operating costs due to the proposed regulations." Sierra confuses my comments with a critique of the design and structure of their fleet turnover model, which was not intended. Instead, as explicitly stated in my comments to Vermont, "the basic effect continues to be based on the *overstated vehicle price* and *understated vehicle utility* assumptions of the commenters." [emphasis added] Sierra has stated on several occasions that the incremental Pavley vehicle price is at least three times larger than any associated efficiency benefits. Moreover, they assert that the most likely manufacturer compliance strategy will involve a dramatic shift in the types of vehicles available to Pavley consumers. Since these assumptions are the basis for the predicted reduction in new vehicle sales and fleet turnover, the predicted impacts are valid only in the context of ones confidence in those underlying assumptions. To the extent those assumptions are in question, the predictions of the fleet turnover model are equally questionable. While I would certainly be interested in reviewing fleet turnover model function and associated coefficient derivation in more detail, I have not performed such an analysis to date and my comments in regard to the accuracy of its fleet impact estimates are based on the pessimism of the underlying Sierra market assumptions. In effect, even the predictions of a perfect model are only as good as the associated input data and in this application, the fleet turnover model depends directly on vehicle price and utility benefits that are in question.

The sensitivity of the model to these input assumptions can be inferred by comparing the three fleet turnover prediction scenarios included in the analysis spreadsheets provided with Sierra's Vermont comments. Two of these scenarios are included in Sierra's written comments. One is included only as an analysis spreadsheet, so its derivation is somewhat uncertain. The Sierra "two car" scenario reflects those impacts deemed "most likely" by Sierra based on a compliance strategy where manufacturers greatly restrict vehicle availability in Pavley states. The Sierra "nationwide" scenario is based on a "less likely" compliance option where manufacturers seek to retain full model availability in Pavley states. Both of these options rely on Sierra's estimated vehicle price and utility impacts, and impact estimates for both are presented in their written material. A third scenario, labeled as the "CARB scenario" on the associated analysis spreadsheet, is included with Sierra's analytical materials, but not discussed in their written material. Although certainty is not possible since the analysis spreadsheet includes virtually no descriptive information, it appears as though this scenario reflects impacts estimated using the Sierra fleet turnover model in conjunction with CARB vehicle price and utility impacts.

Figure 2 presents a comparison of the predicted fleet impacts for the three scenarios. As indicated, 60-70 percent of the predicted reduction in new vehicle sales, the predicted reduction in overall fleet size, and the predicted increase in average fleet age "disappear" when the nationwide compliance scenario is compared to the two car compliance scenario. Since the two car scenario is asserted to be a more economical alternative to manufacturers, this comparison illustrates the "extreme" sensitivity of the fleet turnover model to vehicle availability. In effect, consumers elect not to purchase new vehicles due to restricted model availability rather than as a direct result of Pavley price or utility impacts (since those impacts are present in both scenarios). Therefore, the two car compliance strategy itself (as opposed to Pavley) will be responsible for an approximate 25 percent reduction in new vehicle sales if the fleet turnover model is accurate.

More importantly, Figure 2 shows that about 90 percent of the predicted fleet impacts disappear when the two car scenario is compared to the CARB scenario. For the CARB scenario, new vehicle sales decline by a modest 3 percent, fleet size declines by a marginal 1 percent, and average fleet age increases by 0.2 years (2 months). Thus, the real question is not whether the fleet turnover model introduces any new information into the Pavley evaluation process, but whether the Sierra or CARB vehicle price and utility impacts are more reasonable.

Figure 2. Sensitivity of Sierra Fleet Turnover Model (Impacts for 2030)



12. On page 4, Sierra asserts that my comments that “the Fleet Turnover Model assumes that old vehicles are driven the same number of miles per year as new vehicles” is factually incorrect. They further state that the Sierra modeling approach assumes that “per-vehicle VMT for all vehicles would increase by the same relative factor” so that “the relative differences among age-specific per-vehicle VMT estimates would remain unchanged (usage rates for older vehicles remain lower than usage rates for newer vehicles).” While the scope and precise meaning of my comment may have been misinterpreted, it is nonetheless factually correct as can be easily demonstrated through a consideration of a deferred new vehicle purchase (or purchase chain).

If I elect to purchase a new vehicle, my travel will generally increase in accordance with the increased economic utility of the newer vehicle (relative to the vehicle it replaces). This is generally reflected in the age-specific usage rates of models such as MOBILE6 and is consistent with the assertion of Sierra that “usage rates for older vehicles remain lower than usage rates for newer vehicles.” If I elect to not purchase a new vehicle, I instead base on my travel demand on the attributes of the vehicle I retain and the economic value (if any) of the decision to defer the new vehicle purchase (as well as on other demand influences that do not change as a result of my purchase or non-purchase decision). No one else in the fleet is affected, so their travel demand is under no pressure to change.[25] Thus, the only vehicle in the fleet that is affected is mine. For total fleet VMT to remain unchanged, I *must* increase my travel with my existing vehicle to the same level as I would have accrued with the new vehicle, for which a purchase was deferred. In effect, I must value the two alternatives equally and the VMT of my retained (old) vehicle must be identical to the VMT that would have been assumed had I purchased a new vehicle.

This does not mean that all vehicles have the same VMT, simply that the VMT change that would have been associated with the purchase of a new vehicle is made up by a VMT increase from a single older vehicle. The rest of the fleet has no interest in my purchase decision and would certainly not increase their VMT to offset any decrease in mine. Vehicle purchase is an individual decision with individual impacts, not a fleet decision with fleet impacts. Of course, as the fleet turns over this same decision is repeated until there is a net fleetwide change in VMT, but that change is the net result of a series of individual older vehicle VMT increases. The bottom line is that by assuming constant VMT, “non-replaced” vehicles *are*, in fact, assumed to travel the same distance as the foregone “replacement” vehicle in the year the “non-purchase” decision is made. From that point, annual VMT would again decline in accordance with a decreasing vehicle utility function, but the net effect is that a step change in vehicle utility is assumed (and that is all my original statement implied).

So the only truly relevant question is whether such a step change in travel demand is warranted. In the absence of Pavley, we know that the consumer purchasing a new vehicle has made a value

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[25] On a practical basis, my decision may well carry through a used car sales chain since the vehicle I would have replaced may have been purchased by a used vehicle buyer, which would, in turn, initiate another potential resale until such time as a replaced vehicle is scrapped rather than resold. However, each of these vehicle resales is subject to the same economic decision-making as the new vehicle purchase, so that the net effect on travel demand is unchanged relative to a single purchase decision. Note also that this has nothing with increased used vehicle valuations, since the vehicles in the resale chain will be non-Pavley vehicles until such time as multiple replacement vehicle cycles have occurred. It is only the relative value of the Pavley versus the non-Pavley vehicle that is altered and this has no effect of the resale of two non-Pavley vehicles.

judgment that the increased economic utility of the replacement vehicle is greater than the economic utility of retaining the vehicle being replaced. We also know that with Pavley, the economic utility of the replacement vehicle is lower than alternative replacement without Pavley (since new vehicle sales decline). This has two implications. First, a vehicle actually replaced should generate a lesser economic benefit than would otherwise have been the case and the VMT increase associated with that replacement should, therefore, also be less than would otherwise have been the case (in effect, the VMT of replacement vehicles should be lower with Pavley than without).[26] This should affect 75 percent or more of potential vehicle replacements according to Sierra's estimated two car scenario fleet turnover impacts, and a significantly greater percentage for the nationwide and CARB scenarios. Second, deferred replacements do garner a temporary increase in utility (relative to a replacement alternative) due to the deferred new vehicle expenditure, but this increase can only result in a net increase in VMT if the value of the deferral is greater than the net present value of the future replacement (since that replacement will ultimately be incurred and, therefore, detract from future year utility). Since there is no reason to suspect that vehicle pricing will not keep pace with inflation, it seems quite unlikely that any net VMT increase will be associated with purchase deferrals. Regardless, this should affect at most 25 percent of potential vehicle replacements according to Sierra's estimated two car scenario fleet turnover impacts, and a significantly lower percentage for the nationwide and CARB scenarios.

Finally, what affect can the 15 percent in reduction in overall fleet size under the two car scenario have on overall VMT? If I elect not to replace my vehicle, what incentive does the reminder of the fleet have to subsidize my travel demand? None, other consumers are entirely unaffected by my decision. This is simply an individual determination that the economic cost of vehicle ownership does not justify the value associated with the VMT that vehicle would accumulate. Certainly I can shift some or all of that VMT to a second vehicle that I might own, in effect consolidating the fleet. But I have yet to view any statistical analysis of VMT demand that does not find a positive and significant correlation between VMT and vehicle ownership. In fact, one need look no further than Sierra's own VMT rebound analysis to see that VMT is highly related to vehicle stock (i.e., fleet size).[27] In short, the opportunity to travel decreases with decreasing vehicle ownership and the decreasing size of the Pavley fleet (as predicted by Sierra) is not consistent with an assumption of constant VMT.

In summary, it is virtually certain that the economic response that will result from a decreased vehicle utility function will be a net decrease in VMT, commensurate with the reduced utility and increasing age of the affected fleet. There is simply no basis to assume that VMT will remain constant (exclusive of any rebound affect, which, as has been shown is also inconsistent with a decreasing utility function).

13. On page 4, Sierra asserts that the "MES comments [that VMT should decline in response to fleet size and age] apparently ignore a key linkage between the vehicle fleet composition and the

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[26] Assuming Sierra's price and utility estimates are correct. Note also once again, the internal inconsistency of reduced vehicle sales due to decreased vehicle utility and a VMT rebound assumption that can only be viable if vehicle utility increases.

[27] From Table A-1 of Appendix A of Appendix B of Appendix D of Sierra's Vermont Pavley comments, vehicle stock is a significant and direct influence on VMT at 99 percent confidence (coefficient = 0.407, standard error = 0.116).

pattern of vehicle miles of travel. They assert that when "drivers change the fleet composition by reducing the number of new vehicles they purchase and retaining existing vehicles longer, they also change they way they achieve the total desired level of VMT." This is, of course, a true statement since the composition of the fleet is changed. However, what is actually happening here is that it is Sierra that is ignoring a key linkage between vehicle fleet composition and size and the pattern of vehicle miles of travel. Travel demand is not a constant as assumed by Sierra. As discussed in item 12 above, travel demand is a function of economic utility and fleet size. As shown above, Sierra's own statistical analysis performed in support of their VMT rebound analysis clearly demonstrates this linkage.

14. On page 4, Sierra asserts that my comments that if "total VMT were to remain constant with a reduced fleet, vehicle scrappage would occur sooner (on a timewise basis) than assumed in the commenters analysis and the net effect would be an offset in the assumed fleet turnover emissions impact" ignores the fact that vehicle utility functions are affected by increasing new vehicle prices. This is not correct. What I stated was that the scrappage function itself is also affected by the utility function. Yes, increasing current vehicle utility relative to a potential replacement can defer scrappage. However, by increasing the per-year VMT in response to the relative utility increase (as Sierra has), the time duration of that increased utility is compressed relative to the time duration that would be available under an unchanged per-year VMT function. Since VMT is not a parameter in the Sierra fleet turnover model (only age and price are represented), the time compression of accelerated vehicle use is not captured. As stated clearly in Appendix B of Appendix C of Sierra's Vermont Pavley comments, the fleet turnover model is calibrated to current survival rates, which in turn depend directly (among other parameters) on per-year mileage accrual rates. There is simply no feedback mechanism within the fleet turnover model to access the scrappage impacts of increased mileage accrual rates. In effect, the predicted scrappage rates assume no such increase and, therefore, represent worst-case vehicle retention impacts. My point is solely limited to the assertion that any increased vehicle retention will be offset to some extent by the accelerated depreciation of vehicles due to increases in per-year mileage accrual rates. This is both economically sound and appropriate.[28]

15. On page 5, Sierra asserts that my limited empirical data demonstrating that growth in new vehicle sales in Vermont after that state's adoption of the LEV-II program has exceeded growth in national new vehicle sales during the same time period is irrelevant. I have already addressed this issue above, but would like to respond to the statements that a "useful statistical analysis of the LEV II program would control for the other variables that influence new vehicle sales in Vermont and thus would estimate the independent effect of the LEV II program relative to the effects of other influences on vehicle sales" and that such "a study would essentially compare sales in Vermont under the LEV II program to what sales would have been without the program." In general, such statements are true, but they are also somewhat misleading. A useful statistical analysis would attempt to control for other parameters influencing vehicle sales. However, this is also possible through empirical observation by comparing different populations that vary in either a known way or in only a single parameter. Granted, the constraints associated with my Vermont work prohibited a detailed analysis of the relationship between

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[28] Keep in mind that even this ignores issues unrelated to engine life that may lead to even greater constraints on available vehicle life. For example, wintertime effects in the northeast have a significant impact of vehicle body life and it is not clear that this life can be extended regardless of replacement vehicle pricing. While, such issues may be important to overall fleet impacts, they are not important to the economic arguments I offer herein.

national and Vermont-specific parameters, but unless there is significant deviation in these parameters, the empirical data will exhibit a direct comparison of NLEV versus LEV-II sales trends. I am not stating with certainty that this is the case, but to dismiss empirical data as meaningless is shortsighted (since one can never have empirical data that documents both outcomes of alternative futures). The bottom line is that the expected sales relationships are not observed and until empirical evidence is provided that demonstrates why sales growth in Vermont with the LEV-II program outpaces national sales growth without the LEV-II program, the empirical data is an interesting albeit unnecessary indicator of the significance of fleet turnover effects.

16. On page 6, Sierra makes what is undoubtedly my fondest assertion of the compendium of their comments, namely that it "is sometimes difficult to understand precisely what points the MES comments [related to the VMT rebound effect] are trying to make, but none of these comments is valid." In effect, although they cannot understand the focus of the comments, the comments must nonetheless be wrong. Confidence!

17. On page 7, Sierra asserts that my statement that "the commenters' [i.e., Sierra's] main assertion regarding the inaccuracy of the California VMT rebound analysis centers on the improper treatment of consumer income, stating that a proper analysis would be based on disposable income" is the result of a misunderstanding of "one of the key problems with the Small-Van Dender study performed on behalf of CARB," in that while "the difference between personal income and disposable income may be important, it was not the fundamental issue related to income," which was instead that the "income variable should reflect state-specific price levels, which the Small-Van Dender study failed to do." I am somewhat confused by this entire assertion for several reasons. First, my comment that is in question serves no role in the issues I raised as important to Vermont, except by way of providing background information. It offers no critique of Sierra's work (and, in fact, can only be construed as agreement with one aspect of their approach) if one reads it in the context of the surrounding comments. Second, the terminology "disposable income" as used in my comment is simply a qualifier intended to capture the full effects of the Sierra statistical analysis corrections, which included a shift from total personal income to disposable income and the inclusion of a state-specific cost of living adjustment. Other than that, my comment neither signifies nor implies anything further.

18. On page 7, Sierra asserts that, contrary to my Vermont comments, the VMT rebound effect would not be affected appreciably by considering the "income effect" of new vehicle price increases. This is essentially a correct assertion and does point out a descriptive shortcoming in my comments. However, it does not alter the fundamental concern that the Sierra-estimated rebound affect does not fully consider the full range of Pavley vehicle price and efficiency impacts (also as estimated by Sierra).

The underlying issue at play here is whether or not VMT increases can be expected if total vehicle costs result in a net economic disbenefit to the consumer (as claimed by Sierra). Unfortunately, in my Vermont comments I portrayed this as an income versus operating cost issue and that was (and is) incorrect. Both increased vehicle price and improved vehicle efficiency affect the per-mile cost of vehicle operation and should be viewed as contributing factors to the net change in vehicle operating cost per mile. My discussion of this issue in the introductory VMT rebound section of this memorandum, clearly illustrates that the net change in Pavley cost per mile impacts is substantially reduced when increased vehicle prices are properly considered. Since Sierra considers the efficiency improvements in isolation, they overestimate the Pavley rebound effect. Thus, although my explanation for Vermont was erroneous, the net effect is unchanged.[29]

19. On page 9, Sierra asserts that a modest empirical comparison I performed of VMT and gasoline price changes in Vermont "does not provide any meaningful estimates of the VMT rebound effect in Vermont." Since this comparison was prepared in a constrained timeframe, does not attempt to correct for other socioeconomic influences on VMT, and most importantly has no impact on the various weaknesses of the Sierra analysis, I see no need to defend what was essentially an illustrative exercise. I will leave further interpretation to stakeholders. Note, however, that this same issue is discussed in a bit more detail below in the context of my responses to specific additional assertions made in Appendix G of the Sierra Massachusetts report.

20. Finally, on page 10, Sierra asserts that my description of a "VMT buffer" makes no economic sense because "the effect of higher gasoline prices on travel does not prevent changes in fuel efficiency from affecting travel" so that high historical fuel prices cannot create a buffer preventing the rebound effect. This is a simple misunderstanding of what I termed (for lack of a better description) as the buffer effect. I am not implying in any way that the existence of such a buffer will affect the rebound effect. What I am saying is simply that if the VMT rebound effect is as large as Sierra claims it to be, then VMT should have declined dramatically over the past two years. This decline in VMT will result in a corresponding decline in criteria pollutant emissions. Therefore, even if Pavley leads to an increase in VMT (through the rebound effect), then this increase (which will lead to a corresponding increase in criteria pollutant emissions), will be from a baseline that is lower than that estimated by regulators in the absence of the higher fuel prices. Only when the rebound exceeds the "negative" rebound effects of the fuel price increase, will criteria pollutant emissions exceed those assumed in regulatory air quality plans. That is all that is meant by the term "buffer," and it makes perfect economic sense.

<u>Further Responses to Assertions in Appendix G:</u>

21. On page 1 (and continuing through page 3), Sierra asserts that my claim that they have significantly overestimated the VMT rebound effect by failing to adjust operating cost reductions for increases in vehicle purchase price is "not true and the comment reveals a misunderstanding

[29] The primary reason the issue cannot be treated on the basis of income is that the affect of the vehicle price change disproportionately affects only a portion of income expenditures (i.e., those allocated to transportation, about 20 percent of total expenditures according to the Bureau of Labor Statistics). If one looks only at the transportation "income" affect, the net expenditure increase due to Pavley is equal to about 10 percent ($4,000 Sierra-estimated Pavley impact on vehicle price relative to a $3,732 average expenditure per year [*Bureau of Labor Statistics, "Consumer Expenditures in 2003"*] over an estimated 10 year vehicle replacement schedule), which when adjusted for the higher sensitivity of VMT to "income" (according to Sierra's statistical analysis) produces an effect that is commensurate with the Sierra-estimated vehicle efficiency impact. However, as Sierra rightly points out, this is not an appropriate approach and is offered solely as a counterpoint to the income calculations included on pages 8-9 of Appendix F of the Sierra report to Massachusetts (which erroneously rely on the fact that vehicle purchase expenditures reflect only a modest share of income disposition to imply that the estimated increase in vehicle price is irrelevant from a VMT standpoint). I should also note that Sierra is correct in that I did mislabel Appendix D as Appendix C and that Sierra's estimated new vehicle sales of 8 million per year is low by about a factor of two. However, neither of these errors alters the conclusions of a proper per-mile impact analysis.

of the formulation of consumer response in the analysis." Sierra goes on to describe the basis of the statistical analysis and the development of elasticity estimates, as well as provides what is purported to be a worst case estimate of the effects of new car price increases -- showing that consideration of such effects, although trivial, would actually increase the rebound effect. Although I appreciate the attempted indoctrination, the entire exposition is misleading at best and nonsense at worst. While I would like to think that common sense alone would suffice to indicate that a vehicle for which a consumer pays three times as much in additional purchase costs as they ever receive in fuel cost benefits (as per Sierra estimates, not mine) would offer no incentive for increasing travel (which would only serve to further exacerbate economic disbenefits), I will more rigorously demonstrate the continuing weakness in the statistical VMT formulation and its application by Sierra.

Let's start with the fact that the authors of the original statistical analysis that Sierra has co-opted clearly recognized the weakness of their statistical model formulations with regard to vehicle price impacts. As quoted directly from section 6.3 of their report:[30]

> Second, greenhouse gas regulations that cause manufacturers to raise fuel efficiency are likely to increase the cost of manufacturing vehicles and therefore the price of new vehicles. This would cause some reduction in vehicle stock and, according to our findings, that in turn would reduce the amount of driving. In principle, our equation system could be used to estimate such an effect. The elasticities shown in the second panel of Table 4 tell us what to expect from such a calculation. These estimated elasticities are very small, amounting to a long-run decrease in travel of 0.1 percent for every 10 percent rise in new-vehicle prices. *However, it should be cautioned that this measurement is based on the statistically insignificant coefficient of pv (new-vehicle price) in the vehicle stock equation. There was not a great deal of variation in the price of new vehicles over the 36 years of our sample, and there was none across states in our data set because we could not find a price index for individual states. Therefore, the most reliable conclusion would be that the price elasticity of new car purchases is not measured well by these data and therefore the ultimate effect of changes in new car prices on amount* [sic] *of driving is uncertain.* [emphasis added]

As Sierra states in their comments, the VMT rebound model developed by California researchers "consists of a system of three equations that predict the number of vehicles owned per adult; the average fuel economy level of the vehicles; and the VMT per adult. The theory of consumer behavior underlying the model formulation is discussed in Section 5 of the UC Irvine report." They then go on to claim, based on model results, that "the increased price of a new vehicle will lead consumers to own fewer vehicles (per adult) but, as we shall see, to continue to demand nearly the same level of VMT per adult. The demand for travel will be accomplished by operating each vehicle more miles per year. *Essentially, the usage equation says that consumers require a certain value for VMT per adult, which is affected in only a small way by the number of vehicles owned.*" [emphasis added] This is an egregious misrepresentation of the model and what it "says."

The VMT model is actually quite sensitive to vehicle stock (fleet size), with short and long run elasticity estimates (0.041 and 0.209 respectively), similar in magnitude to those of fuel price

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[30] "*A Study to Evaluate the Effect of Reduced Greenhouse Gas Emissions on Vehicle Miles Traveled*," Final Report, ARB Contract Number 02-336, prepared by Kenneth A. Small, Ph.D. and Kurt Van Dender, Ph.D. of the University of California, Irvine for the California Air Resources Board, March 2005.

(-0.054 and -0.293 respectively).[31] However, the vehicle stock model is *not* sensitive to vehicle price, so that forecasted changes in vehicle price are estimated to produce little (in fact, zero) change in vehicle stock. If there is no change in stock, the sensitivity of the VMT model to stock changes is irrelevant. So the key question then is whether the stock model is reliable.

I have already presented one extract from the original report for the statistical analysis that indicates that the authors themselves clearly recognized that the stock model was questionable. In Section 5.3.1 of the same report, they add further that the "vehicle stock equation (Table 2) is less satisfactory for purposes of tracking price effects because neither the price of a new car nor the cost of driving a mile have a significant effect on the vehicle stock." Recognize that they make this claim of non-significance in a statistical sense only and are, in fact, questioning the model precisely because they would expect such parameters to have a significant effect of stock. In fact, their model shows that vehicle stock is affected by only two parameters, the ratio of adult population to road miles and the ratio of licensed drivers to adults. In contrast, the model shows that vehicle price, fuel price, income, and loan interest rates have no effect on vehicle stock. Sierra cites the effects of these latter parameters as minor, but in fact they are not statistically different than zero and that is how they should be interpreted.

When Sierra states that "the usage equation says that consumers require a certain value for VMT per adult, which is affected in only a small way by the number of vehicles owned," they are misrepresenting the usage model. The usage model *is* affected in a significant way by the number of vehicles owned. However, it is not affected in their Pavley analysis because the vehicle stock model with which it interacts is *not* affected by vehicle price changes. It is this insensitivity that "demands" constant VMT, not the insensitivity of VMT to fleet size. So ultimately we must determine the validity of the stock model, a validity which I clearly question, and which the designers of the original analysis themselves appear to question. One test of any statistical model is whether its formulation comports with reality. Can we make a determination of whether the stock model does or does not accomplish this? I believe that we can using basic engineering considerations.

If we critique the vehicle stock model in the context of a situation where all parameters but the ratio of adult population to road miles and the ratio of licensed drivers to adults are held constant, then every vehicle scrapped must be exactly offset by a new vehicle purchase and vice versa (to maintain a constant fleet size as required by the model). Under no circumstance is a scrapped vehicle not replaced. This means that even if vehicle prices double, triple, quadruple, etc., no one ever decides to forego vehicle ownership either through vehicle consolidation, transfer to another mode of transportation, or travel demand reduction. In economic terms, the marginal cost of vehicle ownership never exceeds the marginal cost of transportation alternatives, under *any* vehicle pricing conditions. Of course, sales can decline and older vehicles can be retained longer on a one-to-one basis, but this does not alter the marginal cost calculation and adds the additional burden of demanding an infinite vehicle useful life. Clearly the conditions required for such a scenario are nonsensical, but these are the conditions that Sierra is advocating when they embrace the vehicle price insensitivity of the vehicle stock model.

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[31] The elasticity estimates presented here are derived from the model coefficients presented in Table A-1 of Appendix A of Appendix B of Appendix D of Sierra's Vermont Pavley comments.

Regardless, the greatest condemnation of the Sierra VMT rebound approach is that their own fleet turnover model recognizes the absurdity of the constant fleet size assumption. The fleet turnover model is composed of two statistical models that are entirely independent of the vehicle stock model employed in the VMT rebound analysis. As documented above, the fleet turnover model clearly predicts that fleet size is sensitive to vehicle price as Sierra themselves predict an approximate 15 percent decline in fleet size (in 2030) for their two car scenario. How do they rationalize the two conflicting impacts, namely that:

- VMT does not change with vehicle price (because vehicle stock *does not* change with vehicle price, as per the VMT rebound model), and
- Fleet size changes with vehicle price (because vehicle stock *does* change with vehicle price, as per the fleet turnover model)?

They don't. They simply use one assumption in their fleet turnover analysis and the other in their VMT rebound analysis. One or the other (or both) has to be wrong.

We can actually make a crude correction of the vehicle stock portion of the VMT rebound model using Sierra's own data from the fleet turnover model. As described previously, Sierra predicts a 14.6 percent reduction in fleet size (in 2030) under the two car compliance scenario. Using the long run elasticity of VMT with vehicle stock from the VMT rebound model, this would result in a 3.1 percent *decrease* in VMT.[32] If we then compare this to the fuel price component of the VMT rebound effect at an average efficiency improvement of 23 percent, we calculate a VMT *increase* of about 2.9 percent (assuming a long run elasticity of -0.157). As indicated, the VMT decrease due to the vehicle stock effect outweighs the VMT increase due to the fuel price effect, so that the net effect is a 0.2 percent *decrease* in VMT.

While I am not sanctioning the Sierra fleet turnover model as I have already described continuing concerns above,[33] it is clear that the VMT rebound effect predicted under the crudely corrected vehicle stock model is now consistent with real-world expectations as to how consumers would respond when fuel expenditure savings come at the expense of larger (according to Sierra) vehicle price increases. There is no incentive to increase driving, and the corrected model properly reflects that. Whether the magnitude of that effect is accurate remains uncertain, but it is clear that VMT rebound is *not* a significant consideration given the Pavley price and benefits impacts estimated by Sierra.

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[32] It is also possible to re-estimate the elasticity of vehicle stock with vehicle price from the Sierra fleet turnover model. The average new vehicle price in the third quarter of 2005 was about $28,000 including financing and incentives (USA Today, 11/16/2005). If we assume a 5 year loan at 5 percent, this equates to a purchase price of just under $25,000. Using $4,000 as the average Sierra price impact for new vehicles under the two car scenario, the percentage change in new vehicle price would be about 16 percent. Since the VMT portion of the VMT rebound model estimates a 3.1 percent decrease in VMT for this same scenario, the effective long run elasticity of VMT with vehicle price is about -0.19 (as compared to an elasticity of VMT with fuel price of -0.16).

[33] For example, I strongly suspect that the VMT response to vehicle stock is also dependent of the age of the stock, with utility declining with increasing age. If such a relationship did exist, the VMT impacts of reduced fleet turnover would further increase the sensitivity of VMT to vehicle price.

22. On page 4, Sierra asserts that my claim that the income effects of Pavley were not properly considered is erroneous. As described in item 18 above, this is essentially a correct assertion that is related to a descriptive shortcoming in my Vermont comments. In those comments, I was trying to incorporate the vehicle price impacts of Pavley into Sierra's VMT rebound model through the income parameter. This is not a correct approach as described above in item 18, but that does not alter the underlying concern that the Sierra-estimated rebound affect does not fully consider the full range of Pavley vehicle price and efficiency impacts (as estimated by Sierra). That concern continues to be valid as documented throughout this memorandum.

23. On page 4, Sierra asserts that my empirical comparison of VMT and gasoline prices in Vermont is fundamentally flawed and without merit. Although as explained in items 8 and 19 above, there is merit to this assertion as I did not fully consider VMT influences other than gasoline price (instead relying on an assumption that fuel price effects would dominate other short term influences due to the size of observed fuel price changes). However, this in no way affects the various shortcomings of the Sierra analysis. Nevertheless, several additional assertions made by Sierra relative to the empirical VMT analysis are interesting, so I believe additional response is appropriate.

On page 5, Sierra states that "MES arguments based on these data are misleading because no effort is made to account for the effects that growth in population, incomes, and the vehicle stock will have on Total VMT." While this is acknowledged above, it is quite interesting to see vehicle stock listed as a contributor since Sierra consistently claims that total VMT is dependent on individual travel demand and independent of vehicle stock. Regardless, they go on to state that over "a short time period, these factors will generally have much greater influence on the level of total VMT than will gasoline prices." In a situation where gasoline price changes are modest, I would generally agree with this assertion. However, that is not the case for data from 2003 to 2005, where real gasoline prices rose by more than 35 percent. This growth far exceeds short term population and income growth. Since the VMT rebound analysis used by Sierra shows that short term elasticity of VMT with fuel price to be as great or greater than the other factors cited, it is simply not possible for these other factors to have a greater influence on VMT in the short term.

Perhaps most disconcerting is the claim of page 6, that, due to the lagged nature of the rebound effect, "the below-average gasoline prices seen between 2000 and 2003 in the Vermont data continue to exert an effect on VMT per adult in 2005, as do the above-average fuel prices in 2004 and 2005." This is simply not true. Yes, the full effect of gasoline price changes takes some time to fully manifest itself according to the VMT rebound model utilized by Sierra. However, the lagged effect can only continue to exert influence across years if the price change continues to manifest itself. This, of course, may or may not occur in practice, where the gasoline price signal can (and does) change from year-to-year. To assert that consumers continue to respond to historic price changes is absurd. Would any rational driver condition a VMT response on gasoline at $1.35 per gallon if the actual price being paid at the pump is $1.90 per gallon? Consumers instead respond to the current price signal so that the net response of VMT to fuel price is continuously adjusted and any continuing lagged effects are contingent on the consistency of current and prior year price signals.

Although I do not wish to belabor the point of the empirical exercise itself since it only serves to distract from the continuing weaknesses of the Sierra analysis, I must nevertheless make several brief comments with regard to the Sierra rebuttal presentation summarized in Table 2 of Appendix G. This presentation purports to show that the VMT rebound elasticity estimate provides good agreement with observed VMT when income and population increases between 2000 and 2005 are considered. In fact, the supposed agreement is mere coincidence achieved by looking at the VMT predictions for a single year (2005) and ignoring the substantial errors in prediction for other data years.

Before presenting the accuracy of prediction estimates for other data years, let me state that my calculation method differs from that of Sierra. Although I use identical assumptions for income and population growth, I apply the long run income elasticity to estimate yearly changes due to income. This is because the income trend is presumably based on 1990 through 2001 data, so that its effect has had time to affect a repeated series of responses.[34] My population effects are the same as Sierra's since population (assuming equivalent growth for adults and total population) is a direct VMT multiplier (i.e., its elasticity is 1.0). With regard to fuel price effects, I estimate impacts on VMT using both short and long term elasticities. Since the fuel price signal to consumers changes annually (in both magnitude and direction), compounding responses to an average price change (as per Sierra) does not provide a meaningful indication of aggregate consumer response. However, if the elasticities are accurate, then the actual fuel price response will be bounded by the short and long run responses. Such an analysis produces the VMT predictions depicted in Figure 3.

As indicated in Figure 3, the short run fuel price elasticity does produce an accurate VMT prediction for 2005, but that accuracy is dependent on nothing more than an offsetting series of under- and over-predictions of response in each year between 2001 and 2005. Although, as one would expect, the long run elasticity produces less accurate VMT estimates in 2005, it also results in substantially more accurate VMT estimates for 2002 (by "making up" for a significant VMT under-prediction in 2001). Figure 4 depicts the annual VMT changes for both the observed and predicted data, clearly illustrating the offsetting effects of under- and over-predictions for individual years. Finally, Figure 5 illustrates the various fuel price elasticities that are required to produce VMT predictions that match observation.[35] The depicted elasticity estimates are not intended for any purpose other than to illustrate the wide potential for variability. As indicated, there are either significant unaccounted influences or substantial

[34] In effect, the lagged effect of income on VMT has had time to run its course. A fraction of consumers are responding to income changes in 2005, a fraction to income changes in 2004, a fraction to income changes in 2003, etc. Since all of these income changes are identical (at +1.5 percent), the net effect in any given year is a full (i.e., long term) income response, which will continue until such time as the rate of income growth changes.

[35] These elasticities inherently include the effects of all VMT influences other than population and income, which are accounted for separately as per Sierra's growth assumptions. Also, they are not intended to reflect the universe of possible elasticities since there are a large number of possible permutations of the data that have not been considered. For example, one can consider the cumulative annual change since 2000, the cumulative annual change since 2001, the cumulative annual change since 2002, etc. as well as observed growth relative to the preceding year without concern for other historic data. Additionally, since the cumulative functions are recursive, predictions for one year depend directly on elasticity assumptions for the previous year. The depicted data reflect three possible applications of the data. These are: (1) the required elasticity for 2001, 2002, 2003, 2004, and 2005 relative to preceding year VMT without regard to any historic error, (2) the required elasticity for those same years relative to cumulative annual change since 2000 assuming Sierra's short run fuel price elasticity for all prior years, and (3) the required elasticity for those same years relative to cumulative annual change since 2000 assuming Sierra's long run fuel price elasticity for all prior years.

Figure 3. VMT Predictions for Vermont Based on Sierra Fuel Price Elasticity

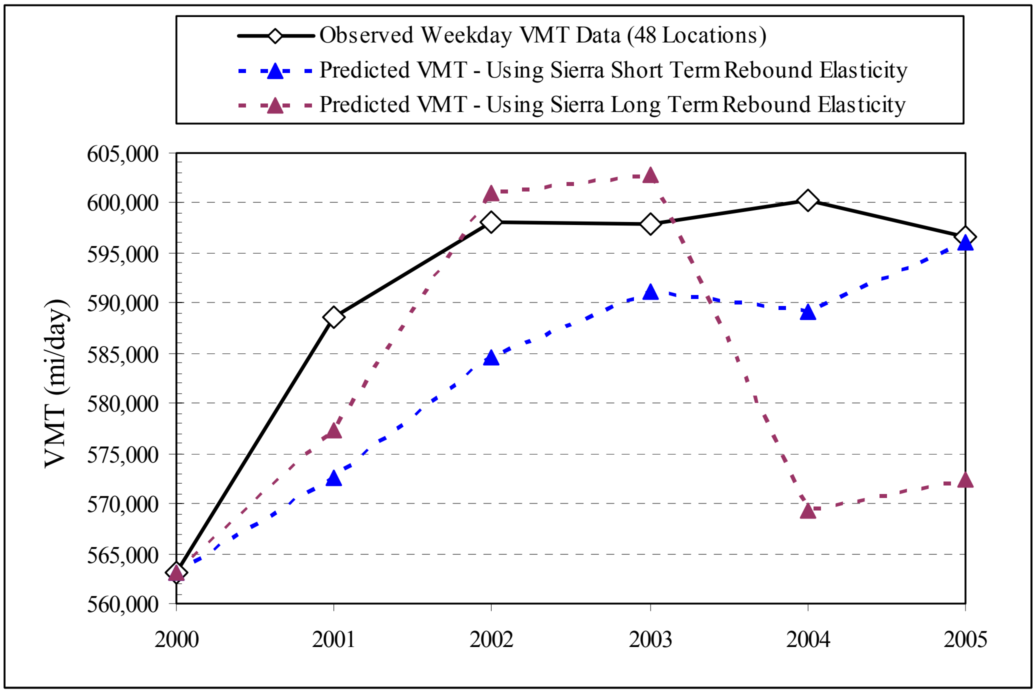


Figure 4. Predicted Changes in Vermont VMT Based on Sierra Elasticities

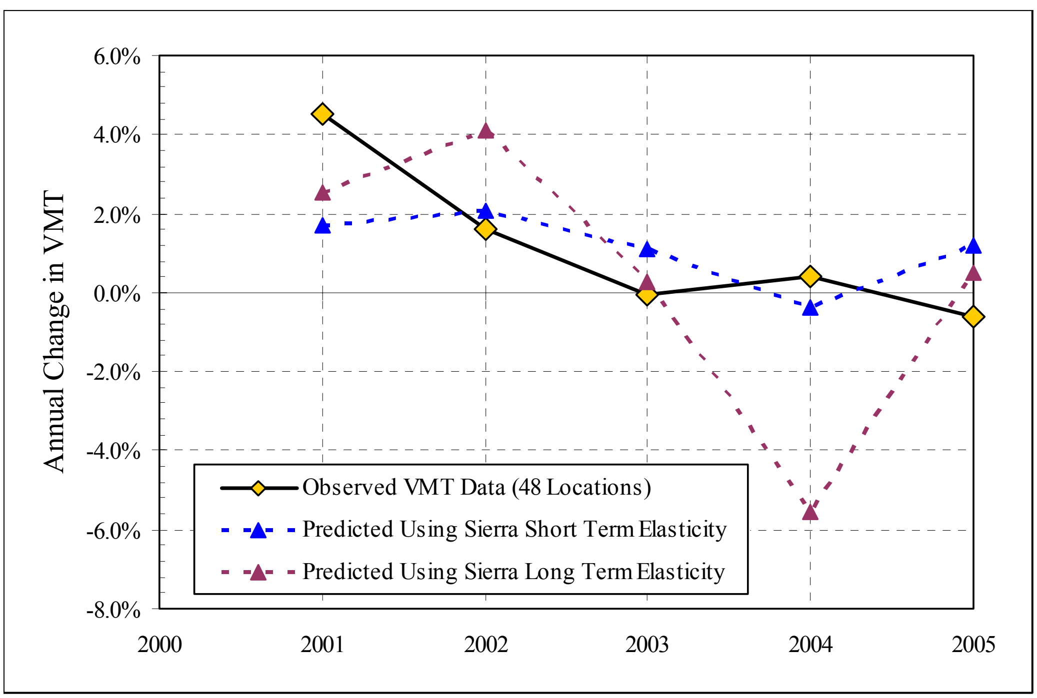
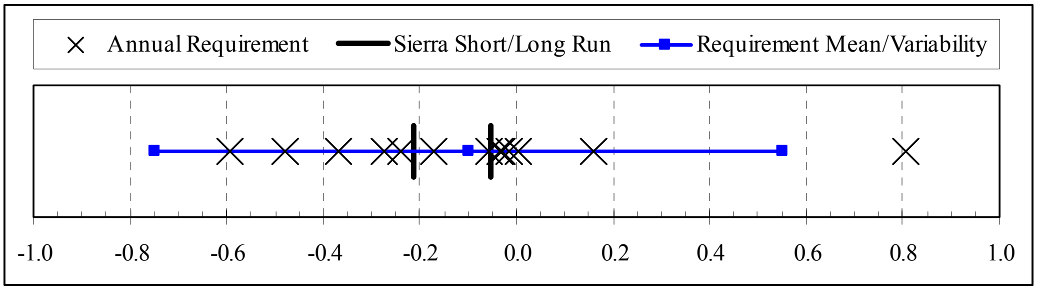


Figure 5. Fuel Price Elasticity Required to Match Observed Vermont VMT



deviation in the historic population or income trends relative to those assumed in this admittedly simplistic analysis.

As Sierra rightly points out, it is important not to place too much emphasis on these empirical data until such time as a substantially more detailed analysis is performed. Unaccounted influences continue to affect derived elasticity estimates and, most importantly, the key weaknesses of the Sierra analysis are entirely independent of these data. While other interpretations of these data may be possible, they in no way affect those weaknesses -- and, therefore, these data should be considered of no importance relative to the theoretical arguments presented in this memorandum.